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WO 02/056787 A2

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(54) Title: OPTICALLY-ENHANCED HALOGEN CURING LIGHT

(57) Abstract: The present invention is directed to optically-enhanced light-emitting resin-curing devices and methods of applying these devices to the purpose of curing resins. This invention permits the use of conventional curing lights and allows for curing resins more rapidly. These curing devices typically include, a conventional curing light source, a lens assembly that focuses the light into a smaller diameter and an optical guide for delivery of the focused light to the resin.

WO 02/056787

PCT/US01/44268

OPTICALLY-ENHANCED HALOGEN CURING LIGHT**CROSS-REFERENCE TO RELATED APPLICATION:**

This application hereby claims the benefit of the priority of U.S. Provisional Patent Application, Serial No. 60/253,085, filed November 28, 2000, and of U.S. Provisional Patent Application, Serial No. 60/262,102, filed January 18, 2001, both of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION:**Field of the Invention:**

The present invention relates to a light-emitting, resin-curing device and a method of applying the light-emitting, resin-curing device to dental resins. More particularly, this invention relates to an optically-enhanced, halogen-light-based resin-curing device that is able to maximize the overall curing and curing rate of dental restorative materials and that allows for dental bleaching, all in a cost-efficient and timely manner.

Description of Related Art:

The field of dentistry has evolved such that caries, cavities and other irregularities in a person's teeth can be bonded, sealed or filled with resins (which, in the present context, also include polymers). In view of this, the increasing use of resins to fill caries or to fix other dental irregularities has resulted in the need for quick-curing resins and for devices and methods that promote the efficient and quick curing of resins.

WO 02/056787

PCT/US01/44268

1 Specifically, the need for more efficient and better bonding or sealing
2 materials has led to dental support companies producing high-quality resins and
3 resinous materials. In addition to these high-quality resins and resinous materials,
4 there has been an increased focus on curing the resins and resinous materials in a
5 uniform manner to ensure that there is no shrinking or cracking.

6 The curing of the resins can be done with one of several available light-
7 emitting, curing devices. However, the types of light-emitting, curing devices that
8 are used today can be broken into two different categories: (i) conventional-light-
9 emitting curing devices and (ii) high-intensity-light-emitting curing devices.

10 The conventional-light-emitting curing devices, that typically include
11 tungsten halogen lamps or bulbs as the light source, have been used in the dental
12 industry for a long time. These conventional-light-emitting curing devices
13 typically have the advantages of long operable lifetimes, dependability and
14 affordability.

15 Conventional-light-emitting curing devices cost substantially less than the
16 more expensive, high-intensity-light-emitting curing devices. For example, a
17 typical conventional-light-emitting curing device can cost as little as between
18 \$1,000 and \$1,500. However, there are several drawbacks to the conventional-
19 light-emitting curing devices.

20 Particularly, conventional-light-emitting curing devices require relatively
21 long curing times. For example, it is common for a conventional-light-emitting
22 curing device to take 30-40 seconds to cure resinous materials. In addition,
23 conventional-light-emitting curing devices, such as those that make use of
24 tungsten halogen lamps or bulbs, do not focus enough light energy (watts of

WO 02/056787

PCT/US01/44268

1 power) into a small enough spot size to be transmitted through an optical path of
2 approximately six feet in length. When such transmission is attempted, there is
3 typically not enough energy to rapidly polymerize dental resins at the other end of
4 the path. Rather, the tungsten halogen lamps or bulbs typically have to be
5 positioned within inches of the final delivery point and typically cure photo-
6 polymerizable resins with a small, unfocused cross-section of the total light
7 emitted from the bulb.

8 Hence, the light source has to be operated at a higher power to make up for
9 the unused portions of its total emitted light and conventional-light-emitting curing
10 devices typically must be designed such that a cooling fan is placed close to the
11 bulb. For the sake of convenience, the bulb and a cooling fan are generally built
12 into a hand-held device. However, the hand-held device is noisy, vibrates and
13 blows hot air. Since, in operation, the hand-held device is necessarily held in close
14 proximity to the patient's face, the patient is exposed to unpleasant noise,
15 vibrations and hot air from the hand-held device.

16 The high-intensity-light-emitting curing devices typically include xenon
17 lamps or xenon short-arc lamps that produce greater light energy than the tungsten
18 halogen lamps discussed above. However, the xenon lamps and short-arc lamps
19 are much more expensive and complex in design than their lower-intensity
20 counterparts.

21 Nonetheless, although high-intensity-light-emitting curing devices have
22 only been on the market for about 4 or 5 years and cost approximately \$4,000 to
23 \$4,500, such systems have gained a substantial measure of acceptance. This is in
24 large part due to the fact that the lamps in the high-intensity light-emitting curing

WO 02/056787

PCT/US01/44268

1 devices produce more light energy and therefore cure the restorative materials
2 much faster, usually in as little as 10 seconds, and often in as little as
3 approximately 3 to 5 seconds.

4 The disadvantages of these high-intensity-light-emitting curing devices are
5 that the power supplies required to ignite the lamps are expensive, the light system
6 is complex and the finished product is highly priced.

7

8 **SUMMARY OF THE INVENTION:**

9 Certain embodiments of the present invention are directed to conventional-
10 light-emitting, resin-curing devices that include a light source, a reflector
11 surrounding the light source, and an optical lens configuration or optical system
12 that provides focused light energy for curing dental materials and for other
13 applications. These devices make use of assemblies that combine tungsten
14 halogen light sources with an optical lens configuration that produces the same
15 high-intensity light that is produced by relatively complex and expensive systems
16 with high-intensity xenon curing lamps. The present invention may be described
17 as optically-enhanced, halogen-light-emitting curing devices.

18 Curing dental materials is one application of the present invention.
19 However, other embodiments of the invention include methods and devices, dental
20 or otherwise, that focus light from a relatively low-intensity or low-energy light
21 source into a focused spot of relatively high-intensity or high-energy light and that
22 then propagate the focused light through an optical wave guide or optical fiber.

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WO 02/056787

PCT/US01/44268

1 **BRIEF DESCRIPTION OF THE DRAWINGS:**

2 The present invention will be further described by FIGS. 1-3. These
3 figures are solely intended to illustrate various preferred embodiments of the
4 invention and are not intended to limit the scope of the invention in any manner.

5 **FIG. 1** illustrates a schematic of an optically-enhanced, light-based curing
6 device configuration according to a first embodiment of the present invention.

7 **FIG. 2** illustrates a schematic of an optically-enhanced, light-based curing
8 device according to a second embodiment of the present invention.

9 **FIG. 3** provides specific dimensions and components for use in accordance
10 with certain embodiments of the present invention.

11 Same numerals in FIGS. 1-3 are assigned to similar elements in all the
12 figures. Embodiments of the present invention are discussed below with reference
13 to FIGS. 1-3. However, those skilled in the art will readily appreciate that the
14 detailed description given herein with respect to these figures is for explanatory
15 purposes as the present invention extends beyond these limited embodiments.

16

17 **DETAILED DESCRIPTION OF THE INVENTION:**

18 **FIG. 1** illustrates a first embodiment of an optically-enhanced, light-
19 emitting, resin-curing device. This embodiment includes a light source 10 in the
20 form of a lamp, a first lens 20 in the form of a collecting/collimating lens, a filter
21 40, a second lens 30 in the form of a focusing lens, and an optical wave guide 50
22 (also referred to as a light guide). A reflector 100 is positioned around at least a
23 portion of the light source 10 and reflects light from the light source 10 through an
24 opening in the reflector 100. After leaving the reflector 100, the light travels

WO 02/056787

PCT/US01/44268

1 through the first lens 20, the filter 40, and the second lens 30 and travels toward
2 one end of the optical wave guide 50. The light enters the optical wave guide 50
3 and travels to the location of a curable resin 60 that is positioned in a tooth 70.

4 A fan 80 is positioned in close enough proximity to the device such that,
5 when in operation, components of the resin-curing device may be cooled by the
6 fan 80. The optical wave guide 50 has a proximal end that is adjacent to the
7 second lens 30 and a distal end that is positioned adjacent to the light-curable resin
8 60 and tooth 70.

9 FIG. 2 illustrates a second embodiment of an optically-enhanced, light-
10 emitting, resin-curing device according to the present invention. In this
11 configuration, the reflector 100 focuses light from the light source 10 onto a
12 collecting and collimating lens 20. The light then travels to a second lens 30, that
13 focuses the light onto one end of the optical wave guide 50 after passing through
14 the filter 40.

15 In FIG. 2, a crossover point 90 is illustrated as being positioned between
16 the reflector 100 and the collecting and collimating lens 20. A focal point 110 is
17 also shown in the interior of the filter 40. Representative locations and dimensions
18 for some of the components illustrated in FIG. 2 are provided in FIG. 3, as are
19 specifications for some other components.

20 According to certain embodiments of the present invention, the light
21 source 10 can be a tungsten halogen lamp or other type of lamp. Preferably, a
22 low-energy light source 10 is used such that the resin-curing device of the present
23 invention needs no separate power supply and can be directly plugged into a wall
24 outlet. The only requirement for the light source 10 is that it can be integrated into

WO 02/056787

PCT/US01/44268

1 an optical assembly and focused to generate enough energy to cause rapid curing
2 of the resin 60 or other similar material.

3 The collecting and collimating lens 20 in FIG. 1 collects a portion of the
4 light that is emitted from the light source 10 and collimates it such that it is
5 directed along the optical path. Once collimated, the light is passed through a
6 filter 40 that typically only passes "blue" light between the wavelength ranges of
7 380 nm to 510 nm. The lens 20 in FIG. 2 may also pass the light through a filter
8 40 but this is done after the light passes through the focusing lens 30.

9 Either one or a collection of filters 40 may be used to select the optimal
10 wavelengths of light for curing the resin 60. Hence, infra-red filters and/or ultra-
11 violet filters (not shown) may be added with the understanding that each additional
12 filter results in a loss of light intensity. Other optical components such as, but not
13 limited to, polarizers, beam splitters, and mirrors (not shown), may also be used in
14 the optical lens configuration.

15 According to certain embodiments of the present invention, the filter 40 is
16 not needed because the light source 10 is not a lamp but instead is a source that
17 only emits light in a certain wavelength range. For example, a cluster of light-
18 emitting diodes (LEDs) or laser diodes that only emit at and around the
19 wavelengths needed to cure the resin 60 may be used, eliminating the need for the
20 filter 40.

21 The focusing lens 30 in FIG. 2 takes the collimated, filtered light and
22 focuses it into a spot of relatively high-intensity light. A preferred focusing lens
23 30 is a 30 mm achromatic condensing lens. However, other lenses that may be

WO 02/056787

PCT/US01/44268

1 used include, but are not limited to, aspheric condensing lenses and plano-
2 concave-convex lenses.

3 Although the high-intensity light spot may be positioned directly onto the
4 resin 60, it is preferable to position the spot on the end of a light-channeling device
5 such as the optical wave guide 50. The optical wave guide 50 may be a fiber-optic
6 cable or fiber. According to certain other embodiments of the present invention,
7 the optical wave guide 50 may be replaced with other devices such as, but not
8 limited to, a fiber-optic bundle, a liquid light guide, or a rigid light guide.

9 The optical wave guide 50 allows the dentist (or other operator) using the
10 curing device to direct the light focused onto the proximal end of the optical wave
11 guide 50 onto the resin 60 at a remote location. Preferably, the optical wave guide
12 50 is flexible, approximately six feet long, 7 millimeters or less in diameter, and
13 allows the dentist to position the distal end of the optical wave guide 50 in close
14 proximity to or directly on the curable resin 60 in a patient's tooth 70.

15 The light source 10, the collecting/collimating lens 20, the focusing lens
16 30, the filter 40 and a cooling fan 80 (used to regulate the temperature of the light
17 source 10) are, according to certain embodiments of the present invention, placed
18 within a hand-held device to which the optical wave guide 50 may be attached.

19 Ergonomic configurations for all of the components described above will
20 become apparent to one skilled in the art upon practice of the present invention
21 and are therefore not greatly detailed herein. The curing devices can be any
22 reasonable size, but small hand-held devices are preferred. These devices can
23 resemble a pistol, where the light source 10 is positioned very close (within
24 inches) of the final delivery point (the resin). The apparatus illustrated in FIG. 1

WO 02/056787

PCT/US01/44268

1 of U.S. Patent No. 5,147,204 to Patten et al., incorporated herein in its entirety by
2 reference, shows one possible way of encasing the components of the present
3 invention.

4 An advantage of the present invention is that it provides devices where
5 light travels down the optical wave guide 50 that is quiet, compact, small, and easy
6 to maneuver around. This is all achieved by using a light source 10 that generates
7 light with enough power to travel down the length of a six-foot optical wave guide
8 50, and still has enough energy on the end of the guide 50 closest to the resin 60 to
9 effect rapid curing.

10 Although the configuration illustrated in FIG. 2 includes a collimating lens
11 20, a focusing lens 30 and a filter 40, this configuration merely represents some of
12 the possible embodiments of the present invention and is in no way limiting
13 thereof. According to certain other embodiments, as little as a single lens may be
14 used to collect and focus the light from the light source 10 into a smaller diameter,
15 resulting in greater useful light intensity (energy) per cross-sectional area than is
16 normally achieved. The lens 20, 30 described above can further be coated with
17 any optical coatings that are well known in the art and that act as filters to
18 selectively pass only a specific wavelength range of light.

19 The reflector 100 may include a reflective material positioned around the
20 light source 10 such that light emitted away from the optical setup is redirected
21 toward the collecting/collimating lens 20 shown in FIG. 2. Any reflective
22 material may be used, though some materials will be superior to others, dependent
23 on the wavelength of the light to be reflected in order to cure the resin 60. The
24 reflector 100 is typically formed in a shape that reflects the greatest amount of

WO 02/056787

PCT/US01/44268

1 light onto the lenses 20, 30 and includes an opening to allow light to travel out of
2 the reflector 100.

3 A cross-over point 90 is illustrated in FIG. 2 between the light source 10
4 and the collecting/collimating lens 20. This is a point at which the maximum
5 amount of light is focused before re-diffusing onto the surface of the
6 collecting/collimating lens 20.

7 In the optical setup illustrated in FIG. 2, the filter 40 is positioned between
8 the focusing lens 30 and the optical wave guide 50. Within the filter 40 is the
9 focal point 110 of the focusing lens 30. This is the point at which the maximum
10 amount of light is focused before re-diffusing onto the surface of the optical wave
11 guide 50.

12

13 Experimental Data

14 Experiments have shown that dental resins cured utilizing the curing
15 devices and methods discussed above are cured properly. The experiments
16 included measurements of power on both power meters and light intensity meters.
17 It was also demonstrated that embodiments of the invention are able to cure
18 resinous materials 80% as fast as high-intensity light sources. Moreover, the
19 curing devices of the present invention cure greater than twice as fast as
20 conventional-light-emitting curing devices.

21 Several different dental restorative resins were tested utilizing a light-
22 focusing assembly that included a tungsten halogen lamp, a condensing lens and a
23 (M) filter. The lamp was an ELC 250 watt, 24 volt lamp. The lens assembly was
24 a 30 mm achromatic condensing lens with a "blue" filter positioned 0.625" from

WO 02/056787

PCT/US01/44268

1 the lens. The lamp, when used in combination with this lens assembly, focuses
2 down to an 8 mm spot. Curing tests to a 3 mm depth were conducted with the
3 following results:

4 Dental Restoratives Curing Time

DenMat FloRestore Shad A1	3 seconds
DenMat FloRestore Shade A3.5	3 seconds
DenMat Virtuoso Condensable	3 seconds
Ker Herculite	5 seconds

5
6 While the invention has been described in conjunction with the specific
7 embodiments outlined above, it is evident that many alternatives, modifications,
8 and variations will be apparent to those skilled in the art. Accordingly, the
9 preferred embodiments of the invention are intended to be illustrative and not
10 limiting. Various changes may be made without departing from the spirit and
11 scope of the invention.

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WO 02/056787

PCT/US01/44268

1 **CLAIMS:**

2 We claim the following:

3 1. A curing device comprising:

4 a light source;

5 a reflector positioned proximate to the light source and having an
6 opening;

7 an optical lens configuration, positioned proximate to the opening;

8 and

9 an optical wave guide positioned proximate to the optical lens
10 configuration.

11

12 2. The device of claim 1, wherein the light source comprises a low-energy
13 light source.

14

15 3. The device of claim 1, wherein the light source comprises at least one of a
16 tungsten halogen lamp, a laser diode and a light-emitting diode.

17

18 4. The device of claim 1, wherein the optical lens configuration comprises an
19 achromatic condensing lens.

20

21 5. The device of claim 1, wherein the optical lens configuration comprises a
22 collecting and collimating lens.

23

WO 02/056787

PCT/US01/44268

- 24 6. The device of claim 1, further comprising a filter, positioned proximate to
25 the optical lens.
26
- 27 7. The device of claim 6, wherein the filter is positioned between the optical
28 lens configuration and an optical wave guide
29
- 30 8. The device of claim 6, wherein the filter transmits light of wavelengths
31 between approximately 380 nm and 510 nm.
32
- 33 9. The device of claim 1, wherein the optical wave guide comprises a fiber-
34 optic fiber.
35
- 36 10. The device of claim 9, wherein the fiber-optic fiber has a diameter of less
37 than approximately 7 mm.
38
- 39 11. The device of claim 1, wherein the optical wave guide is flexible.
40
- 41 12. A method for curing a resin comprising:
42 reflecting light emitted by a light source towards an optical lens
43 configuration;
44 collecting the light in the optical lens configuration;
45 focusing the light onto a first end of an optical wave guide; and
46 curing a resin at a second end of the optical wave guide using the
47 light.

WO 02/056787

PCT/US01/44268

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49 13. The method of claim 12, further comprising collimating the light in the
50 optical lens configuration.

51

52 14. The method of claim 12, further comprising filtering the light before the
53 light cures the resin.

54

55 15. The method of claim 14, wherein filtering the light comprises transmitting
56 only the light with a wavelength between approximately 380 nm and 510
57 nm.

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WO 02/056787

1/3

PCT/US01/44268

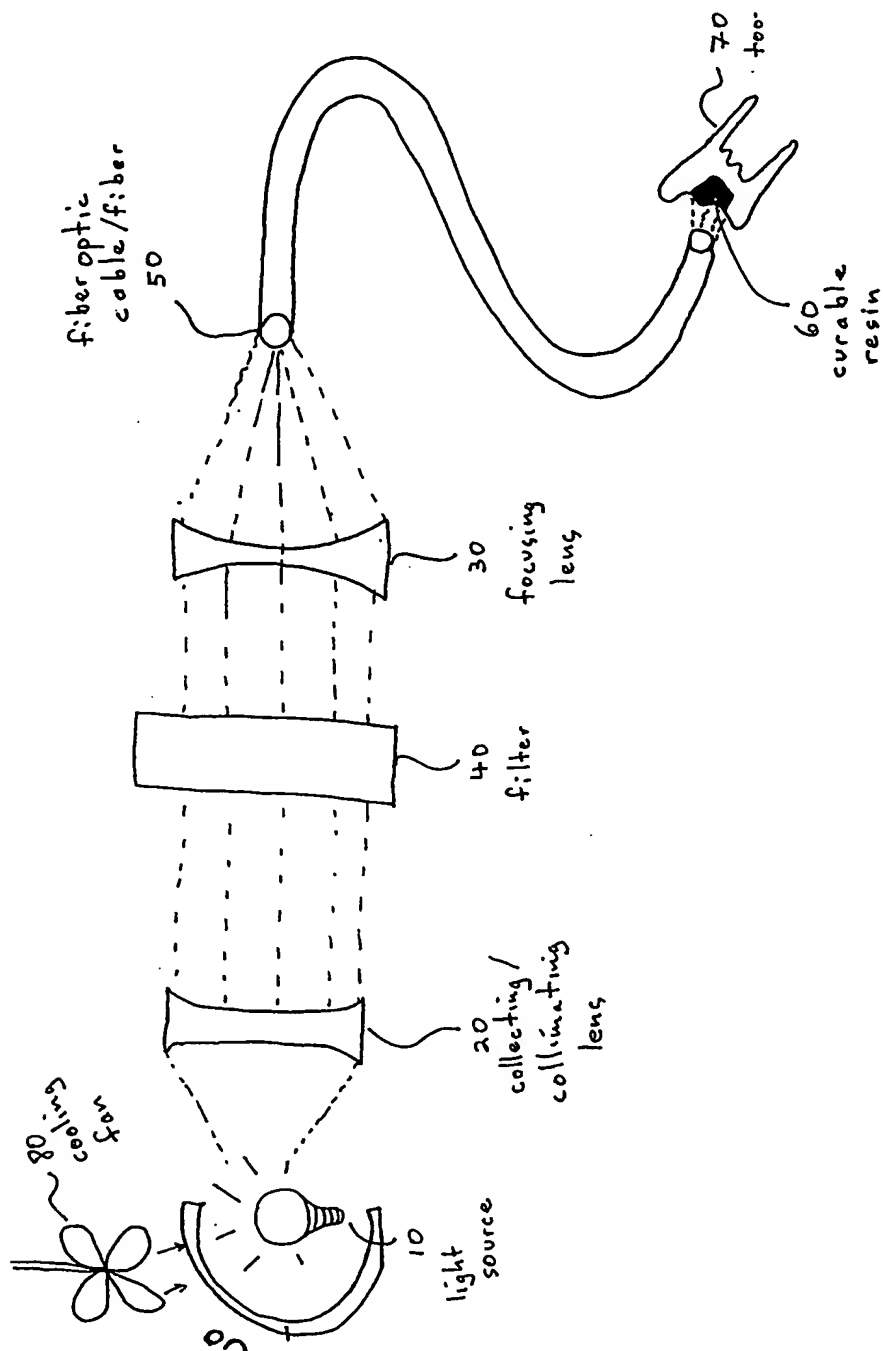


Fig. 1

WO 02/056787

2/3

PCT/US01/44268

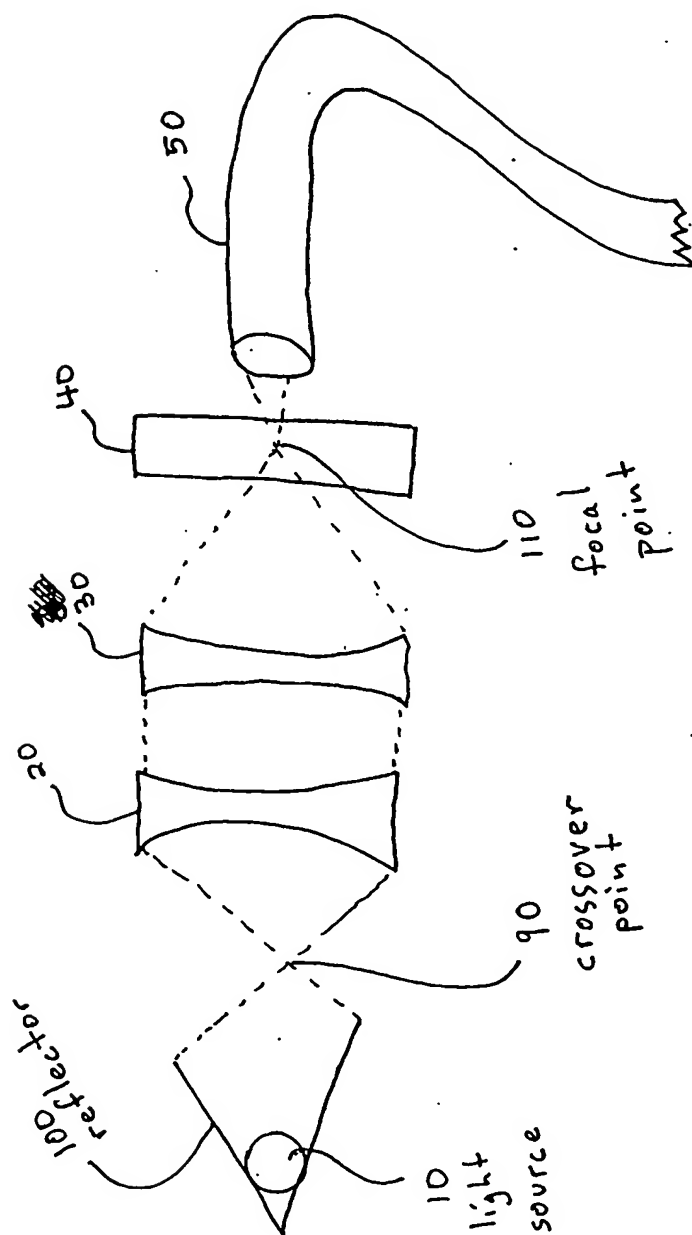
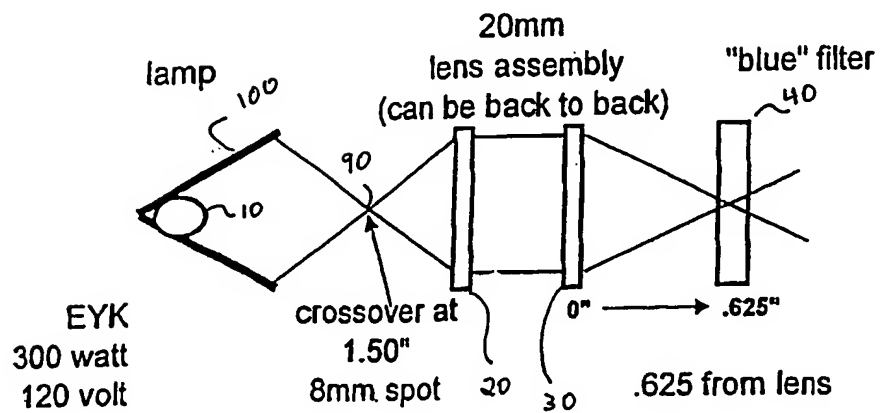


Fig. 2

WO 02/056787

3/3

PCT/US01/44268



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